REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 16. Period--April 1 to June 30, 1945

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The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

WHEAT STORAGE

Studies on the Fluctuations of Insect Populations in Wheat Stored under Different Systems of Management*

The study on the fluctuations in insect populations in wheat stored in Ever-normal granary type bins was continued during the quarter. Five-probe samples were taken from the upper southwest quadrant of 41 bins in the Management Series, and the number of insects by species was determined from the examination of the samples. A summary of the data obtained during the past year is given in table 1. The lesser grain borer (Rhyzopertha dominica F.) and the rice weevil (Sitophilus oryza L.) are classed as "weevils" in the table and all other species are combined as "bran bugs". The comparative abundance of the different species found in the June samples was as follows:

Species	Percent of total
Flat grain beetle (Laemophloeus minutus Oliv.)	60
Saw-toothed grain beetle (Oryzaephilus surinamensis L.)	37
Lesser grain borer (Rhyzopertha dominica F.)	2
Long-headed flour beetle (Latheticus oryzae Waterh.)	1

It may be noted from table 1 that the insect population has remained at practically the same level since the March 31, 1945 sampling.

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* Reported by H. H. Walkden and R. B. Schwitzgebel, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine in cooperation with the Bureau of Plant Industry, Soils, and Engineering.

Table 1.--Summary of the insect populations in the upper southwest quadrant of steel and wood bins, Hutchinson, Kansas, 1944-1945.

Grain storage practice	1944 Apr. 1	July 1	Aug. 1	Sept. 1	Oct. 1	Oct. 15	Nov. 11	Dec. 27	1945 Feb. 9	Mar. 31	June 1
	Average number of insects per 1000 grams										
1000-bushel steel bins											
No treatment:											
9.3% moisture	0 '	0.2	0.4	1.8	1.8	2.4	0.4	0.4	0	0	0.1
	0 "	0.6	1.8	1.8	0.8	1.2	0.6	1.0	0.4	0	1.0
11-11.5% moisture	0.1	0.3	6.0	43.5	28.8	12.8	10.0	5.8	2.4	0	0.1
	1.6	11.4	40.8	57.2	63.2	36.4	34.2	28.2	9.4	8.4	11.4
White walls and roof	0	0	0	3.6	1.2	0.4	0.6	0	0	0	0
	0	1.6	3.6	17.4	6.8	6.4	9.6	2.6	3.0	0.8	3.5
Fumigation in August									0.2	0	0.1
									1.5	0.1	3.4
Fumigation in Sept.	0	0	2.8	24.2$_F$	0.4	0.6	1.0	0.2	0.2	0	0
	0	0.2	12.6	82.8^F	1.2	1.8	6.2	1.4	0.4	0.4	2.4
Fumigation in August	0	0	2.0$_F$	0.2	0.3	0.3$_F$	0	0	0	0	0
and October	0	2.2	8.7^F	0.3	0.6	0.5^F	0.5	0.1	0.1	0.1	0.2
Turn, clean, and	0	0	4.4	8.8$_{TF}$	0.4	0.4	1.2	0	0	0	0.8
fumigate in Sept.	0	0	6.8	19.2^{TF}	0.4	0	0	0.4	0	0.4	0
2740-bushel steel bins											
No treatment:											
White walls and roof	0	0	0	0	0	0	0.1	0	0	0	0
	0.5	0.1	3.3	7.2	5.2	3.5	2.6	1.5	0.7	1.7	1.4
Painted white and grouped for shading	0	0	0	0	0.1	0.1	0.3	0	0	0	0
	0.5	0.6	2.2	4.0	3.5	1.0	1.1	0.6	1.2	1.2	0.5
Fumigation in August									0	0	0
									2.3	1.5	1.1
Fumigation in Sept.	0	0.1	1.0	7.5$_F$	0	0.7	0.1	0.1	0	0	0
	1.8	4.6	5.8	11.8^F	0.8	1.7	0.4	0.4	0.4	1.3	1.2

(continued)

Table 1, continued.

Grain storage practice	1944 Apr. 1	July 1	Average number of insects per 1000-grams Aug. 1	Sept. 1	Oct. 1	Oct. 15	Nov. 11	Dec. 27	Feb. 9	Mar. 31	1945 June 1
Fumigation in August and October	0	0	1.1 F	0	0.2	0	0	0	0	0	0
	0	0	2.2 F	0	0.5	0.1 F	0	0	0	0	0
Turn, clean, and fumigate in Sept.	0	0.5	6.3	61.4 TF	0.1	0	0.1	0	0	0	0
	3.6	13.5	87.9	80.9 TF	0.2	0	0.1	0.2	1.1	0.5	1.5
1500-bushel wood bins											
White walls and roof	0	0	0	0	0.4	0	0.8	0	0	0	0
	0	1.0	10.4	21.2	17.4	14.6	34.4	51.2	23.6	2.4	2.6
White walls	0	0	0.2	0.6	4.2	2.0	1.6	1.2	0	0	0
	0	1.2	7.3	47.2	22.8	25.6	8.0	9.6	2.8	0.8	0.8
Red walls	0	0.2	1.2	2.8	5.6	3.6	3.6	2.0	0	0	0
	0.4	6.8	55.0	60.4	80.2	41.4	22.0	20.4	3.6	1.2	1.6

Legend:

* = Weevils: includes lesser grain borer and rice weevil.
" = Bran bugs: all species except the weevils.
F = Grain fumigated.
T = Grain turned and cleaned.

Winter Mortality of Insect Populations in Wheat Stored in Ever-Normal Granary Type Bins

The rate of winter mortality of insects infesting storcd wheat during the winter of 1943-44 was reported in Report No. 12, pp. 10-13. During the winter of 1944-45 this work was continued, using a larger number of test insects. The test insects were confined in screen-topped, 1-pint cans containing wheat of about 12 percent moisture content. The cans were placed in wooden probes which were forced into the grain to a depth of 30 inches below the grain surface, and thermocouples were located at that point for observation of the grain temperature. The probes were filled with wheat after insertion in the bins. At intervals throughout the winter, the probes were removed and the mortality of the caged test insects was observed. The survivors were returned to the cages and the probes replaced in the bins. Three 1000-bushel steel bins were used in the work: 1 bin with white walls and roof, and two unpainted bins. The probes were placed in the center of the painted bin and in one of the unpainted bins, and in the other, the probe was placed about 3 feet from the south wall.

The results are given in table 2. It may be noted that in the white painted bin, all of the test insects had died by March 3, 1945, while in the unpainted bins some of the rice weevils and saw-toothed grain beetles survived until May 23, 1945, when the experiment was terminated. Observations on the natural insect populations in these bins showed that some insects survived the winter in the unpainted bins. These were found near the south wall.

Table 2.—Winter mortality of stored grain insects caged in stored wheat, Hutchinson, Kansas, winter of 1944-45.

Date of observation	Temperature Deg. F. 30" below surface	Percent mortality: Rice weevil	Lesser grain borer	Long-headed flour beetle	Saw-toothed grain beetle	Red flour beetle
Bin 3-1. White walls and roof (Probe in center)						
November 20, 1944	69	0	0	0	0	0
November 27, 1944	69	7.7	7.1	7.5	0.8	0
December 16, 1944	64	23.5	24.2	32.0	4.5	0
January 13, 1945	54	84.5	51.6	93.9	45.5	56.8
February 8, 1945	47	99.6	95.8	99.9	96.8	100.0
March 3, 1945	44	100.0	100.0	100.0	100.0	
Number of test insects		953	975	949	132	37
Bin 3-11. Unpainted walls and roof (Probe in center)						
November 20, 1944	92	0	0	0	0	0
November 27, 1944	92	2.8	9.7	4.3	6.2	15.4
December 16, 1944	71	25.4	88.9	6.8	44.4	23.1
January 13, 1945	57	38.1	95.5	8.1	51.9	30.8
February 8, 1945	48	61.9	96.5	17.5	51.9	38.5
March 3, 1945	42	79.4	99.7	95.5	60.5	100.0
March 17, 1945	49	92.1	99.9	100.0	75.3	
March 30, 1945	50	98.3	100.0		87.7	
May 23, 1945	52	99.9			93.8	
Number of test insects		1124	1048	898	81	13
Bin 3-10. Unpainted walls and roof (Probe 3 feet from south wall)						
November 20, 1944	76	0	0	0	0	0
November 27, 1944	76	16.2	18.8	5.1	0	0
December 16, 1944	73	23.1	90.0	9.0	4.2	0
January 13, 1945	61	29.2	93.9	16.1	4.2	4.9
February 8, 1945	51	40.7	96.3	42.8	23.9	34.1
March 3, 1945	48	85.1	99.5	90.9	42.3	95.1
March 17, 1945	43	97.8	99.8	100.0	64.8	100.0
March 30, 1945	47	99.8	100.0		81.7	
May 23, 1945	54	100.0			98.6	
Number of test insects		979	1083	951	71	41

Control of Insects Infesting Grain Stored in Wooden Farm Granaries by Means of Interior Wall Treatments

This work, which was begun in the spring of 1944, is being continued during the present year. As a result of last year's work, DDT: 1-trichloro-2,2-bis(P-chlorophenyl)ethane, gave outstanding results when applied to the interior walls of wooden farm granaries as a 5 percent solution in deobase oil. In addition, preliminary trials with venetian red barn paint indicated that this material gave promise of preventing entry by the cadelle into bin walls.

During the past quarter treatments have been applied to the walls of 67 wooden farm granaries located on 20 farms in Reno and Stafford Counties. The granaries range in age from 2 to 60 years, and the wall damage from the cadelle varies from practically none to very severe.

The various treatments are given in the following tabulation:

Treatment	Number treated
DDT, 0.25% in deobase oil solution	1
DDT, 0.5% in deobase oil solution	5
DDT, 1.0% in deobase oil solution	4
DDT, 3.0% in deobase oil solution	10
DDT, 5.0% in deobase oil solution	9
DDT, 0.5%, Deenol 50, in water suspension	5
DDT, 1.0%, Deenol 50, in water suspension	8
DDT, 3.0%, Deenol 50, in water suspension	5
DDT, 5.0%, Deenol 50, in water suspension	4
DDT, 0.5%, Deenol 25EM, in water emulsion	1
DDT, 1.0%, Deenol 25EM, in water emulsion	2
DDT, 1% (Deenol 50), Thanisol, 5%, water emulsion	1
DDT, 1% (Deenol 50), Thanisol, 10%, water emulsion	1
DDT, 1%; Thanite, 5%, in deobase oil	1
DDT, 3%; Thanite, 5%, in deobase oil	2
Thanite, 10%, in deobase oil	3
Thanisol, 10%, water emulsion	1
Thanisol, 15%, water emulsion	1
Venetian red barn paint	2
Ebanol (asphalt paint)	1
Total	67

The Deenol 50 (50% DDT plus water dispersal agent) and Deenol 25EM (25% DDT in water miscible oil) used in these tests were supplied through the cooperation of the Grasselli Chemicals Department, E. I. du Pont de Nemours & Co.; the Thanite and Thanisol by the Hercules Powder Company.

All of the materials were applied to the walls of the bins with a paint spray gun, at a tank pressure of 30 pounds, as a coarse mist. Enough material was applied to wet the wall surfaces without running down the wall. A few days after the treatment was applied, the bins were visited to observe any visible effects of the treatments on the insects infesting the bins. In all cases where DDT had been applied dead insects were found on the floors of the bins next to the walls. In bins treated with Thanite or Thanisol, and also in the painted bins, no dead insects were noted. In one farm bin that was treated with 3 percent DDT in deobase oil, the insects were allowed to collect on the floor for 10 days and then were swept up along 12 feet of wall and counted.

The species and number of each were as follows:

Yellow meal worm adults	604
Yellow meal worm larvae	3
Cadelle adults	127
Cadelle larvae	2
Flat grain beetle adults	193
Small-eyed flour beetle adults	64
Granary weevil adults	6
Rice weevil adults	7
Saw-toothed grain beetle	14
Black carpet beetle larvae	5
Silverfish	4
Windowpane fly larvae	3
Total	1032

In the second 10-day period it was estimated that about as many more dead insects accumulated along this wall.

Varying numbers of dead insects were observed in other bins treated with DDT but no differences were discernible due to reduced amounts of DDT applied, the lowest percentage appeared to be as effective as the 5 percent material.

Only one farm granary was found in which the walls had been bored into by the lesser grain borer.

After the treated bins are filled with the present wheat crop, it is planned to make monthly observations on insect populations, amount of damage, and moisture content of the stored wheat. Similiar observations are to be made in representative untreated bins to serve as checks.

Notes on the residual properties of DDT.

On May 18, 1944, one-half of a wooden granary wall was treated with a 5 percent solution of DDT in deobase oil, the other half received an application of a mixture of dormant tree oil spray, lye, and water. The granary was filled with the 1944 crop early in July and the wheat remained in storage therein until late in February, 1945. During April the bin was visited and large numbers of cadelle adults were observed on the floor next to the wall which had been treated with DDT, but none were found under the portion which had received the dormant tree oil spray.

The bin was swept out on May 21, 1945 and DDT, 5 percent in deobase was applied to the wall which had received the dormant oil spray a year previously, but none was added to the part of the wall treated in May, 1944. Within a few days large numbers of dead cadelles were found on the floor under the treated section of the wall. This would indicate that the dormant tree oil spray had been ineffective for controlling the cadelle.

Late in June, dead cadelle were still being found at the base of the wall treated with DDT in May 1944. Thus it appears that the DDT applied at that time was still effective nearly 14 months later.

Effect of Temperature and Moisture on the Survival and Reproduction of the Granary and Rice Weevils*

In table 3 is summarized data of biweekly observations on the survival and reproduction of the granary and rice weevils at a constant temperature of 75° F. in 9, 10, and 11 percent moisture wheat.

It will be noted that at this temperature there was no reproduction by either the granary or rice weevil in 9 percent wheat, and for each species there was a high mortality at end of the third week. In the 10 percent moisture wheat a few granary weevil survived for 17 weeks, while all of the rice weevil were dead at the end of 9 weeks. A small amount of reproduction was obtained in 10 percent wheat by both species. In the 11 percent moisture wheat there was still an average of 15 percent of the granary weevil alive at the end of 19 weeks, while all rice weevil were dead at the end of the 13th week. A considerable amount of reproduction was obtained for both species in the 11 percent moisture wheat.

Reproduction records for this series of tests are not yet completed, but it will be seen from records to date that here again the amount of reproduction increases as the moisture content of the wheat is increased.

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* Reported by R. T. Cotton and J. C. Frankenfeld, Bureau of Entomology and Plant Quarantine.

Table 3.—Percentage of survival of granary and rice weevils at 75° F. in wheat of 9, 10, and 11 percent moisture content.

Moisture content of wheat and insect used	Percentage of survival after										Number of progeny recovered
	1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks	17 Weeks	19 Weeks	
9% Wheat											
Granary weevil	100	14	8	2	0						0
Do	98	8	6	1	0						0
Rice weevil	98	0									0
Do	75	0									
10% Wheat											
Granary weevil	98	62	27	21	19	16	12	9	4	0	53
Do	100	50	24	19	16	12	8	6	4	1	25
Rice weevil	95	6	4	1	0						7
Do	97	48	1	0							
11% Wheat											
Granary weevil	100	80	67	64	62	45	36	29	22	20	339
Do	95	23	23	23	23	21	17	15	13	10	176
Rice weevil	100	27	21	18	17	4	0				200
Do	100	79	31	26	22	4	0				181

Effect of Temperature, Moisture, and Dockage on the Survival and Reproduction of the Red Flour Beetle

As in previous tests conducted with the red flour beetle, the percentage of survival was found to increase as the moisture content of the grain, and the percentage of dockage increases+ A series run at a constant temperature of 80° F. was completed during the last quarter. The weekly percentages of survival in 9, 12, and 15 per cent moisture wheat with varying amounts of dockage are listed in table 4. In the wheat containing 9 per cent moisture, with no dockage added, the percentage of survival was reduced to 0 per cent by the end of seven weeks. In the other dockage lots in the 9 per cent moisture series, the percentage of survival remained fairly high for 10 weeks with little variation, except that in the lot with 0.5 per cent dockage the percentage of survival dropped more rapidly. However, at the end of 19 weeks, there was practically no difference in the percentage of survival in the lots containing different amounts of dockage.

Increasing the moisture content to 12 per cent extended the period of survival in all dockage variant lots. However, by the end of the 19th week survival in clean wheat and wheat with 0.5 per cent dockage was reduced to 15 and 20 per cent respectively. In the other dockage lots there was no difference in survival which could be attributed to variations in the amount of dockage.

In wheat containing 15 per cent moisture there was no noticeable effect on survival with any of the dockage variant lots. All lots showed practically no mortality after 19 weeks. This would indicate that when the moisture content of the wheat is high enough the red flour beetle is able to obtain sufficient food from whole grain to take care of its dietary needs. Wheat with a moisture content of 9 per cent or less is too hard and dry for this species to feed upon.

As found in previous tests, the amount of reproduction is determined by the number of pupae recovered at each biweekly examination. Table 5 lists the total number of pupae recovered at the end of 19 weeks for the different moisture level wheats, and the percentage of dockage variants. There was only a very slight reproduction in the 9 per cent moisture series. In the 12 and 15 per cent moisture series the amount of reproduction increased as the moisture content of the wheat was increased, and, in general, as the percentage of dockage was increased.

Table 4.--Percentage of survival of red flour beetle in 9, 12, and 15 per cent moisture wheat with varying amounts of dockage at 80° F.

Moisture content of wheat and Food media	Percentage of survival after: 1 week	2 wks.	3 wks.	4 wks.	5 wks.	6 wks.	7 wks.	8 wks.	9 wks.	10 wks.	11 wks.	12 wks.	13 wks.	14 wks.	15 wks.	16 wks.	17 wks.	18 wks.	19 wks.
9% Wheat																			
Clean wheat	100	100	75	50	25	10	0												
Same plus 0.5% dockage	95	95	95	90	90	90	90	90	55	40	15	15	15	15	15	15	15	15	10
Same plus 1.0% dockage	100	100	100	100	100	95	95	90	80	80	65	60	55	55	55	30	20	20	15
Same plus 2.0% dockage	100	100	100	100	100	90	90	90	85	80	80	75	60	60	60	45	45	25	20
Same plus 4.0% dockage	100	100	100	95	95	95	95	90	85	85	75	70	65	65	65	35	25	15	15
Same plus 8.0% dockage	95	90	85	85	85	85	85	85	85	75	65	65	50	50	50	30	20	10	10
12% Wheat																			
Clean wheat	100	100	100	95	95	95	95	95	90	90	70	65	65	65	65	15	15	15	15
Same plus 0.5% dockage	100	100	100	100	100	100	100	100	100	90	55	50	50	50	50	25	25	20	20
Same plus 1.0% dockage	100	100	100	100	100	100	90	90	90	90	90	90	90	90	90	85	85	75	70
Same plus 2.0% dockage	100	100	100	100	100	100	100	100	100	100	85	85	85	85	85	80	80	80	80
Same plus 4.0% dockage	100	95	95	95	95	95	95	95	95	80	70	70	60	60	60	50	50	45	45
Same plus 8.0% dockage	100	100	100	100	100	100	100	100	90	85	80	70	65	65	65	65	60	60	60
15% Wheat																			
Clean wheat	100	100	100	100	100	100	100	100	100	100	95	95	95	95	95	95	95	95	95
Same plus 0.5% dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Same plus 1.0% dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Same plus 2.0% dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Same plus 4.0% dockage	100	100	100	100	100	100	100	100	100	100	100	100	95	95	95	95	95	95	95
Same plus 8.0% dockage	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	90	90	90

Table 5.—Number of pupae of the red flour beetle recovered after 19 weeks from 9, 12, and 15 per cent moisture wheat with varying amounts of dockage at 80° F.

Food media	Number of pupae recovered after 19 weeks in wheat with a moisture content of		
	9 per cent	12 per cent	15 per cent
Clean wheat	0	28	91
Same plus 0.5% dockage	0	67	100
Same plus 1.0% dockage	2	90	154
Same plus 2.0% dockage	2	71	247
Same plus 4.0% dockage	2	113	224
Same plus 8.0% dockage	0	153	341

At 80° F. the first pupae were recovered five weeks after the start of the series. Maximum recovery for all moisture and dockage variant lots occurred during the 6th and 7th weeks, and then gradually dropped off, so that after the 16th week only an occasional pupa was recovered.

In another series of tests, table 6, conducted at a constant temperature of 60° F. using the same moisture and dockage variants, we again find survival increasing as the moisture content of the wheat increases. In the 9 per cent moisture wheat lots, the percentage of survival increases as the amount of dockage is increased. In the 12 per cent moisture wheat the percentage of survival also increases with the increased amount of dockage until the 2 per cent dockage is reached. From this point there is no further increase in survival due to increases in the amount of dockage.

In 15 per cent moisture wheat there is no effect on survival by the absence or presence of dockage.

No reproduction has been obtained to date in any of the moisture and dockage variant lots at 60° F.

Table 6.—Percentage of survival of red flour beetle in 9, 12, and 15 per cent moisture wheat with varying amounts of dockage at 60° F.

Moisture content of wheat and food media	Percentage of survival after 1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	7 Weeks	8 Weeks	9 Weeks	10 Weeks	11 Weeks	12 Weeks
9% Wheat												
Clean wheat	95	80	30	6	0							
Same plus 0.5% dockage:	100	90	70	50	50	25	25	25	0			
Same plus 1.0% dockage:	95	90	85	55	45	30	30	30	10	5	0	
Same plus 2.0% dockage:	95	95	95	75	75	65	65	65	50	25	5	5
Same plus 4.0% dockage:	95	95	80	70	55	40	35	35	25	15	15	5
Same plus 8.0% dockage:	95	95	80	75	70	50	45	45	30	25	15	10
12% Wheat												
Clean wheat	80	80	80	50	50	50	45	45	40	35	30	20
Same plus 0.5% dockage:	100	95	95	90	85	80	80	80	40	40	30	10
Same plus 1.0% dockage:	95	95	95	90	90	90	85	85	65	60	45	45
Same plus 2.0% dockage:	90	90	85	85	85	85	85	85	80	80	75	75
Same plus 4.0% dockage:	100	100	95	95	90	90	90	90	65	65	60	60
Same plus 8.0% dockage:	100	100	90	80	75	75	75	75	75	75	60	60
15% Wheat												
Clean wheat	100	100	100	95	90	90	90	90	90	90	90	90
Same plus 0.5% dockage:	95	95	90	90	90	90	90	90	90	85	80	80
Same plus 1.0% dockage:	100	90	90	90	80	80	80	80	80	80	80	80
Same plus 2.0% dockage:	100	90	90	90	90	85	85	85	80	75	75	70
Same plus 4.0% dockage:	100	100	100	90	90	90	90	90	80	80	75	75
Same plus 8.0% dockage:	100	95	95	95	85	85	85	85	75	70	70	65